NOAA El Niño Rapid Response (ENRR) Field Campaign

Ryan Spackman (STC) and Randy Dole (CIRES)
and ENRR Science Team

NOAA Earth System Research Laboratory
Physical Sciences Division

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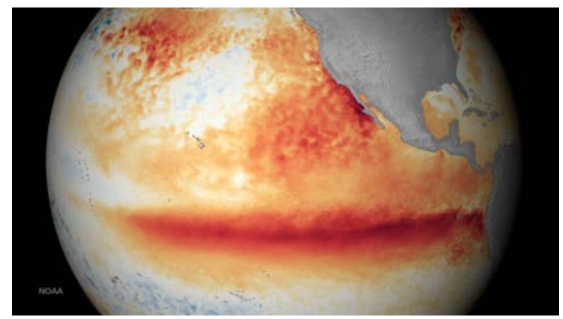
Overview

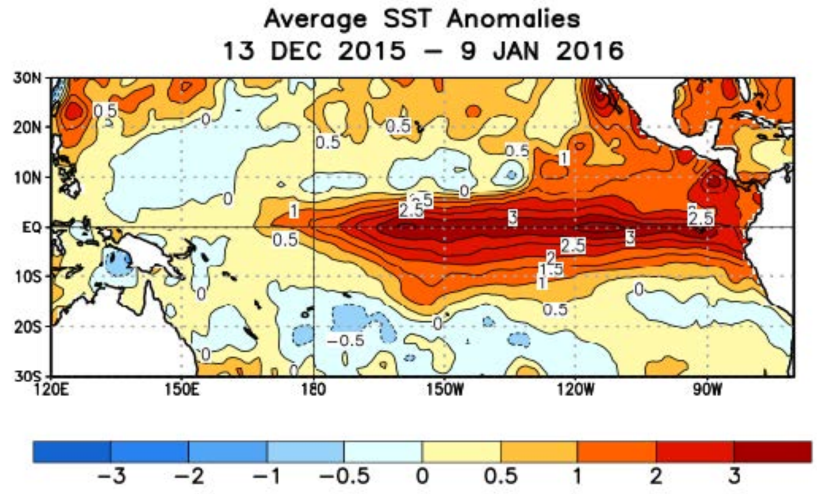
Overarching Goal: Determine the atmospheric response to the major 2015-16 El Niño and its implications for predicting extratropical storms and west coast rainfall



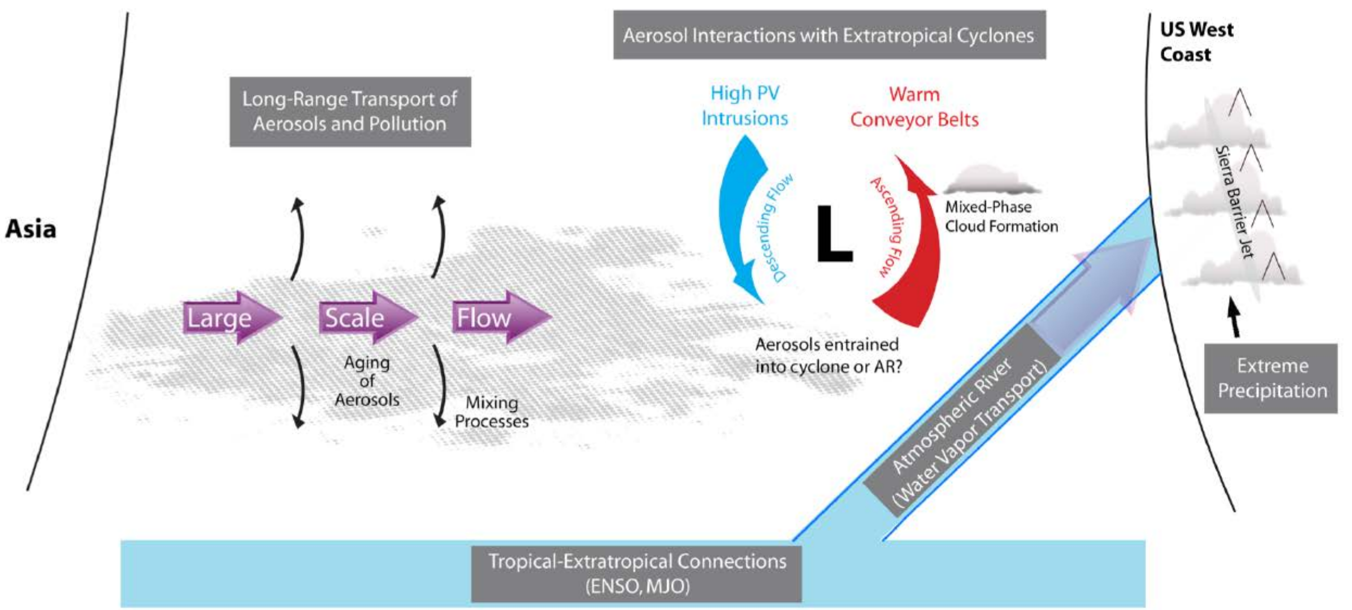
- Conducted the first field campaign targeting central tropical Pacific convection at the heart of an ongoing El Niño
- Planned and executed in less than 6 months
- Observe and understand the physical processes characterizing the first step in the chain leading to North American weather impacts
- Identify data assimilation and satellite uncertainties and model deficiencies

El Niño Rapid Response (ENRR)

- 2015-16 very strong El Niño is among top three on record
- Interesting differences from 1982-83 and 1997-98 with a more central Pacific focus in 2015-16 and variable downstream weather impacts in continental U.S.



ENRR Website: www.esrl.noaa.gov/psd/enso/rapid_response



Courtesy of J. R. Spackman, NOAA Earth System Research Laboratory

ENRR Focus:

- Initial atmospheric response to deep convection in central tropical Pacific during El Niño
- Linkages between outflow from convection across the subtropical jet to extratropical impacts along the U.S. West Coast

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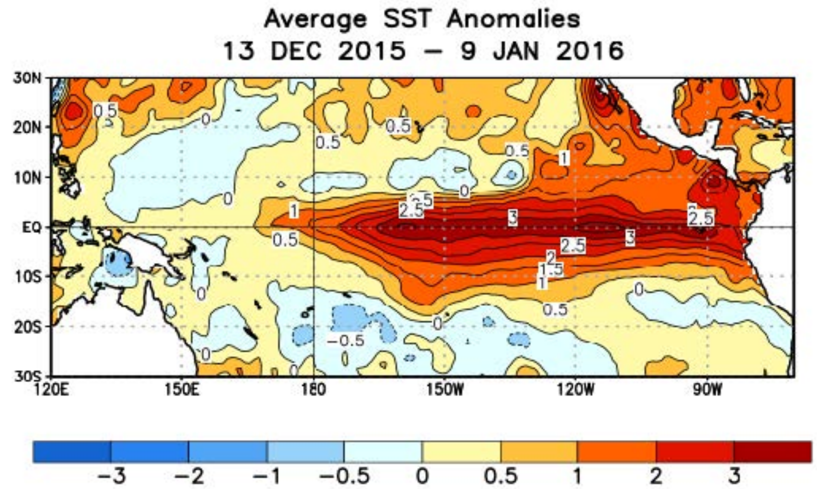

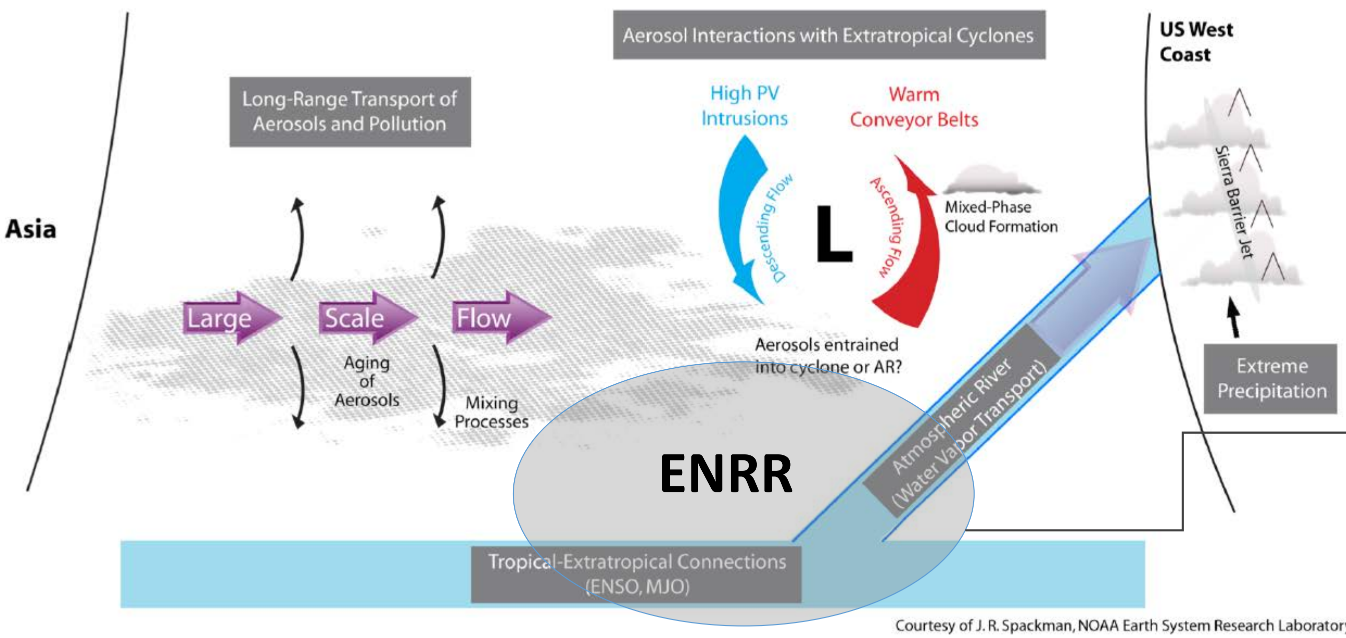

ENRR Focus:

- Initial atmospheric response to deep convection in central tropical Pacific during El Niño
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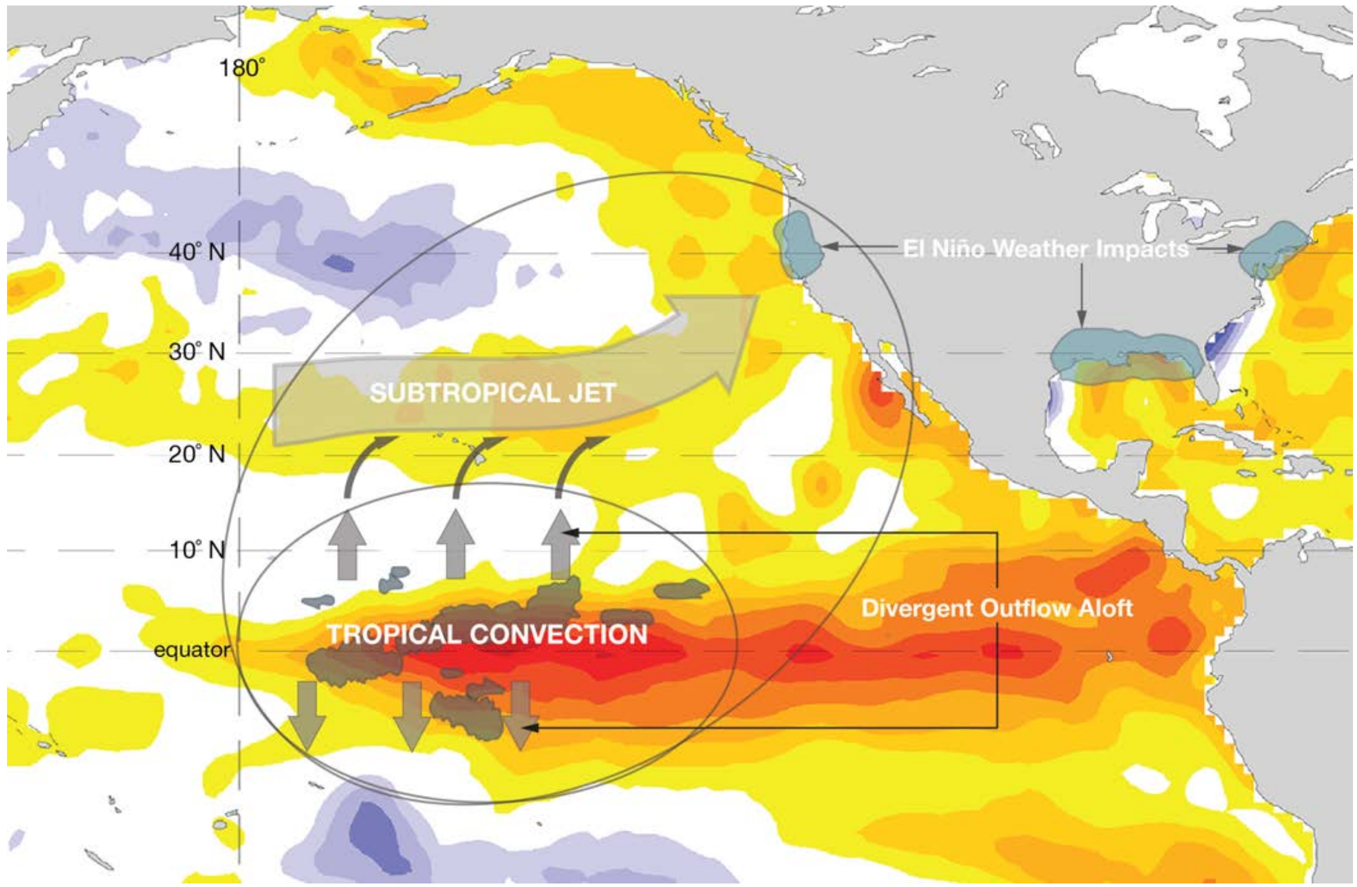
ENRR Science Questions

- How well do weather and climate models represent the tropical atmosphere's response to El Niño – the first step in the cascade of events connecting El Niño to global weather and climate impacts?
- To what extent do kinematic and thermodynamic observations near large-scale convection in the *sparsely* observed central equatorial Pacific during El Niño improve high-impact forecast metrics in the continental U.S.?



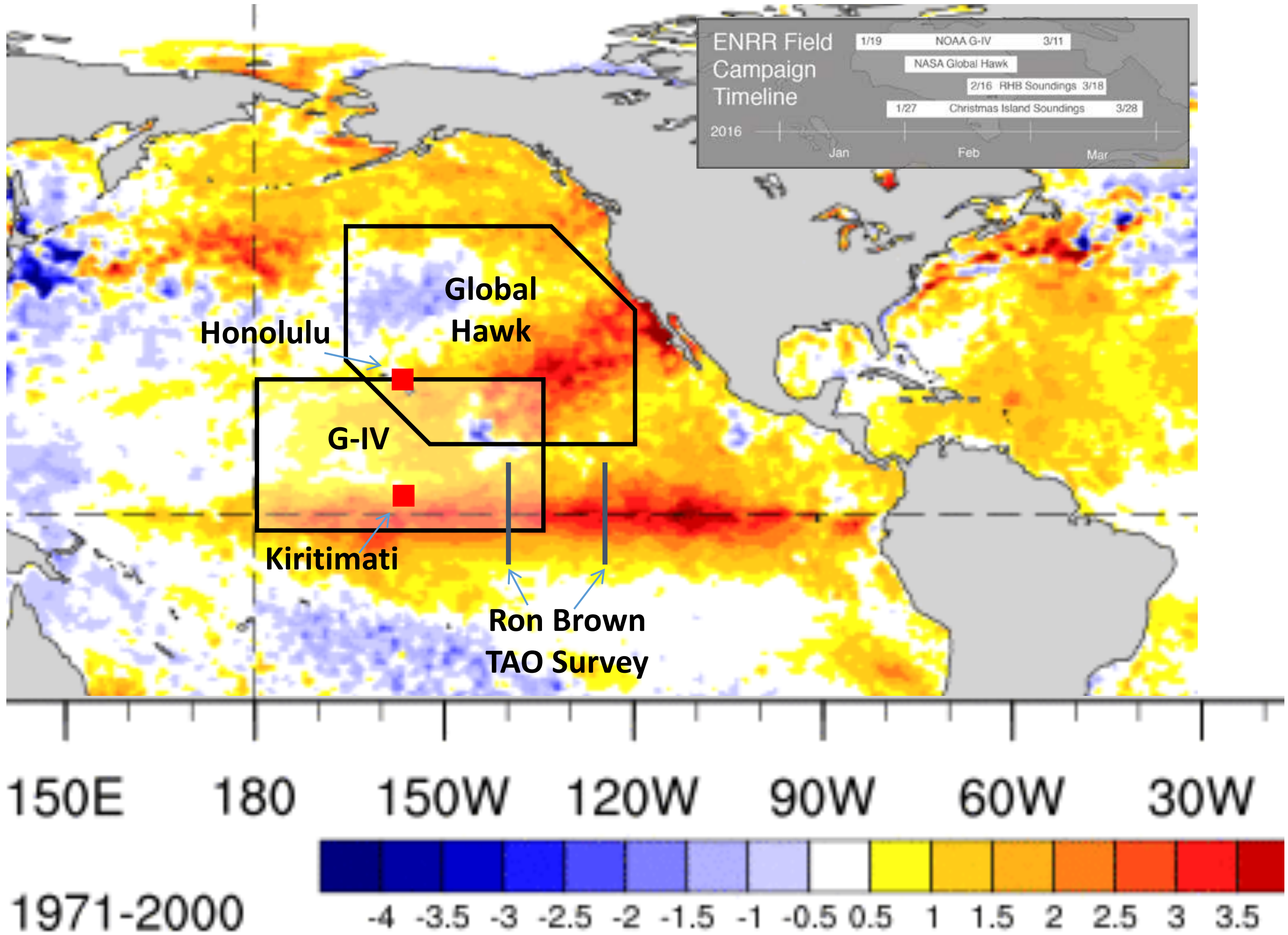
NOAA ENRR Field Campaign, Jan-Mar 2016

- NOAA G-IV conducted 22 science flights in 53 days from 19 Jan to 11 Mar operating from Honolulu and targeting outflow from deep convection north of the equator with dropsondes and tail doppler radar
- NASA Global Hawk completed 3 research flights (~24 hr duration) in 3 weeks in Feb operating from NASA Armstrong Flight Research Center and was supported by NOAA UAS SHOUT (Sensing Hazards with Operational Unmanned Technology)
- Radiosondes were launched twice daily on Kiritimati Island, 25 Jan – 28 Mar
- Radiosondes were launched up to 8 times daily from the NOAA Ron Brown during a TAO survey from Honolulu to San Diego, 16 Feb – 16 Mar, between 8°N and 8°S along 140°W and 125°W

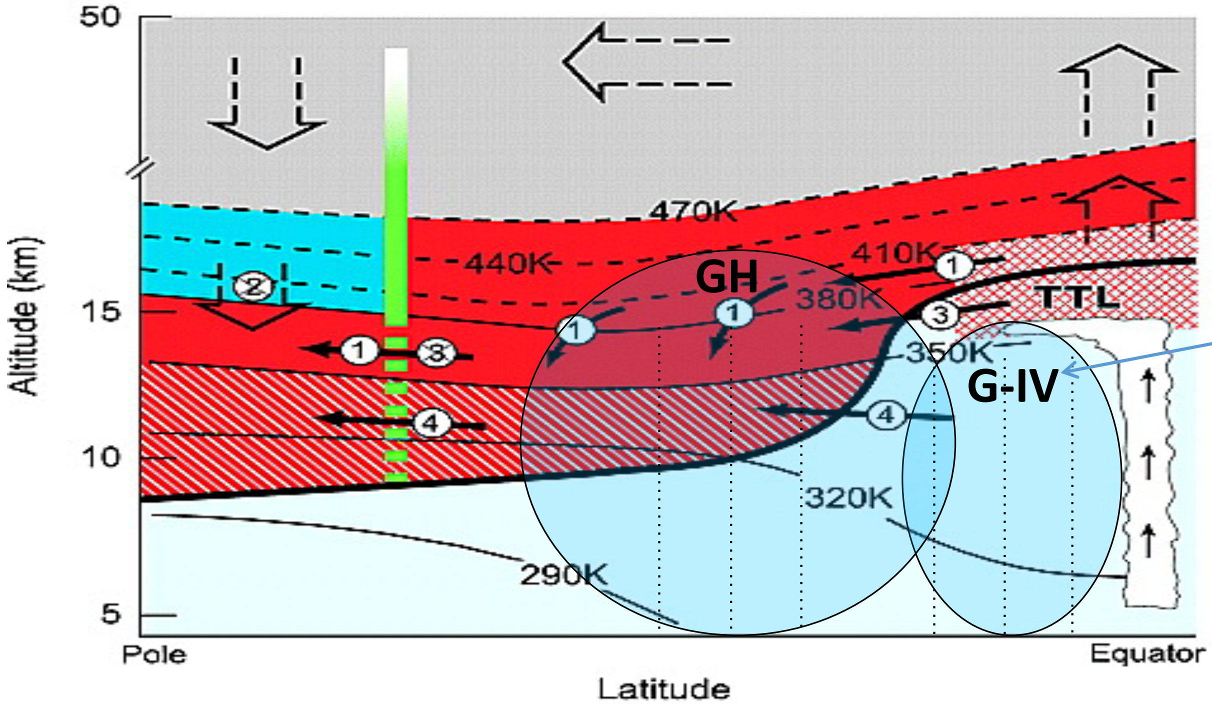
ENRR Implementation Strategy

- G-IV: Divergent outflow and jet extension processes in central and eastern tropical Pacific
- Global Hawk: Coupling to midlatitude weather with surveys in eastern Pacific midlatitudes to evaluate impacts on U.S. West Coast
- Kiritimati/Ron Brown: Survey of atmosphere and ocean conditions in eastern tropical Pacific

SST Daily Anomalies (°C), 25 Oct 2015



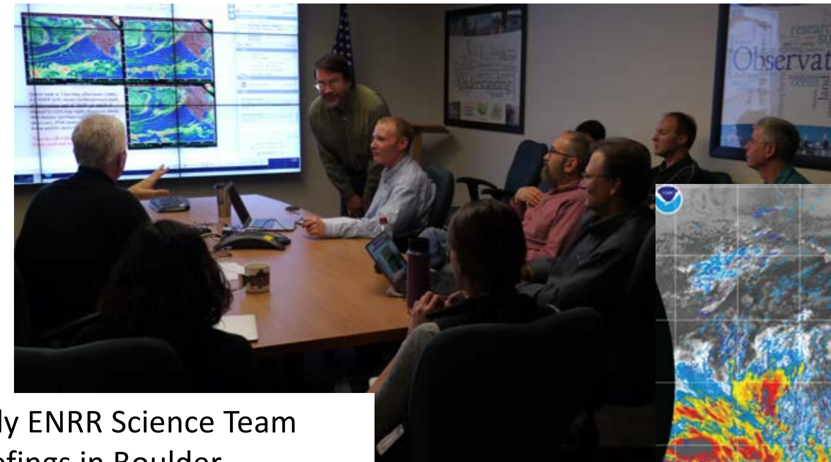
Meridional Perspective on Flight Strategies

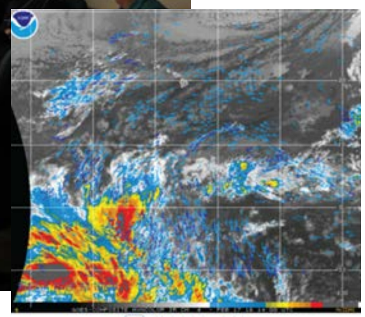


- G-IV: Divergent flow aloft in central/eastern tropical Pacific mostly reachable by G-IV at altitude of 12-14 km and captured by dropsonde measurements
- Global Hawk: Survey the subtropical jet and deep tropics where convection may extend above G-IV altitude

Journal of Geophysical Research: Atmospheres
Volume 112, Issue D12, D12308, 27 JUN 2007 DOI: 10.1029/2006JD007618
http://onlinelibrary.wiley.com/doi/10.1029/2006JD007618/full#jgrd13277-fig-0001

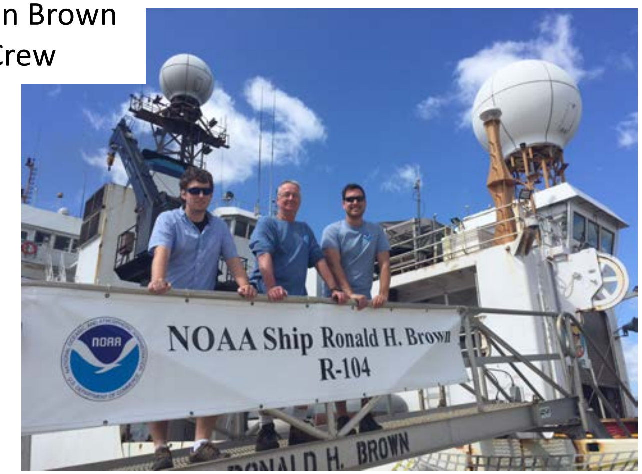
NOAA ENRR Field Campaign, Jan-Mar 2016





Daily ENRR Science Team Briefings in Boulder

NOAA Ron Brown Science Crew



NOAA G-IV Implementation Team in Honolulu

Radiosonde launch at Kiritimati Island

ENRR Field Campaign Summary

- 718 dropsondes deployed

  NOAA G-IV: 628 sondes in 22 research flights

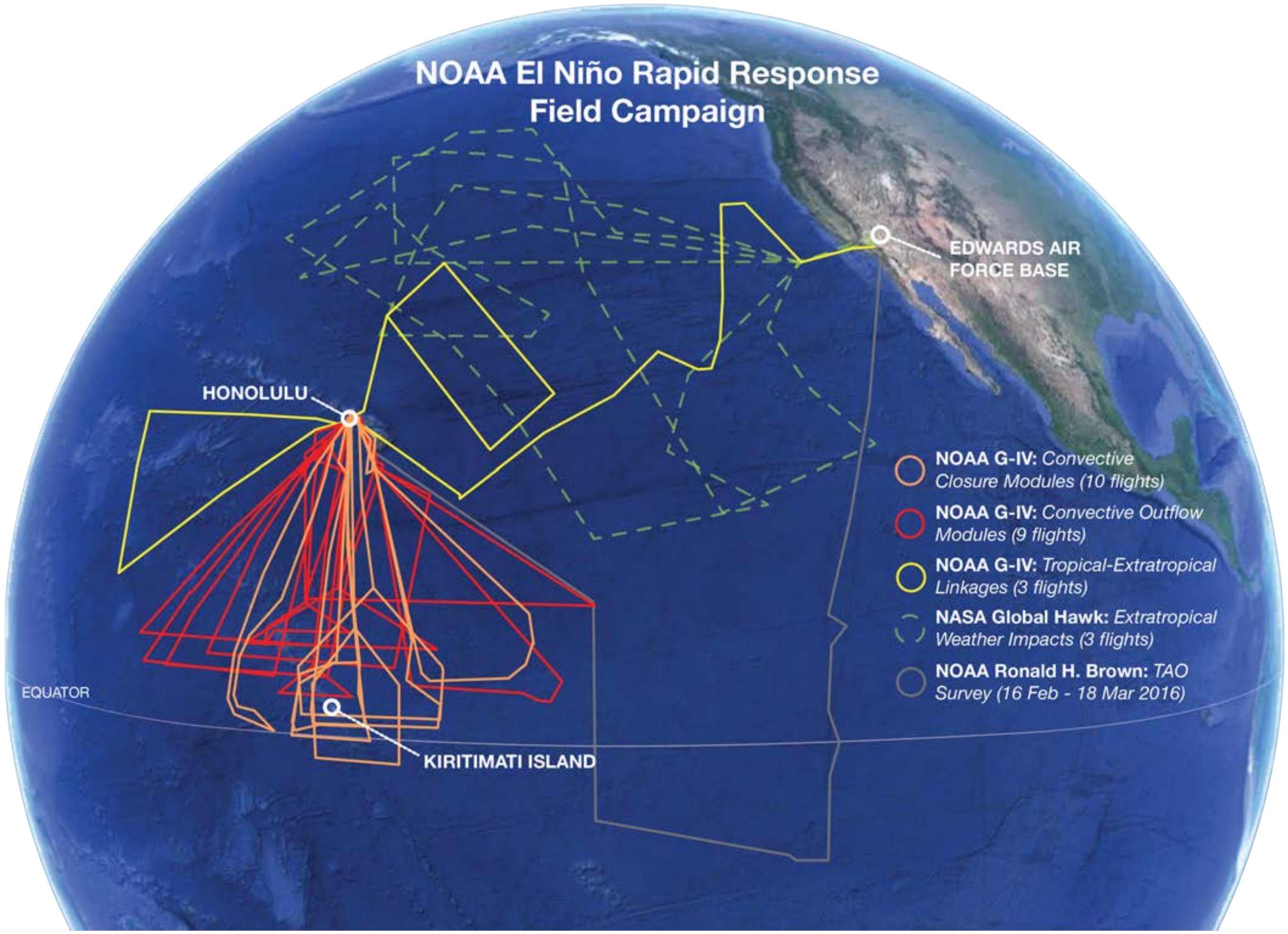
  NASA Global Hawk (SHOUT): 90 sondes in 3 science flights

- 336 radiosondes launched

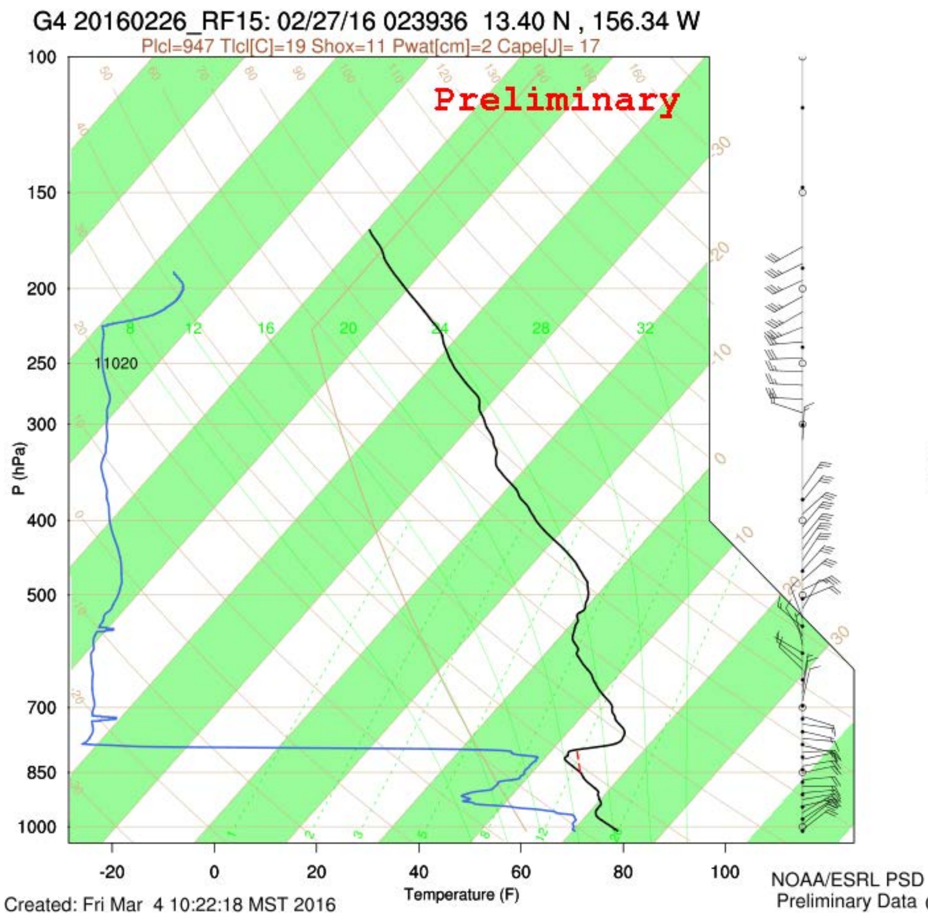
  NOAA Ron Brown: 193 sondes

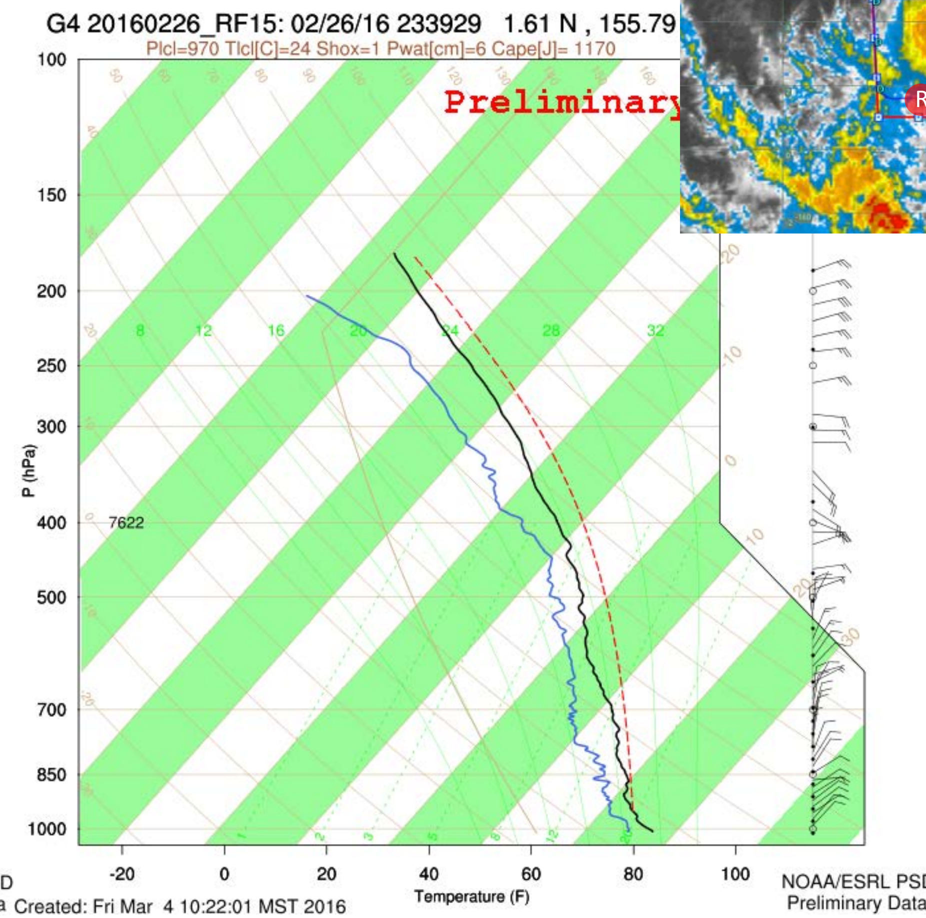
  Kiritimati (2.01°S, 157.40°W): 124 sondes

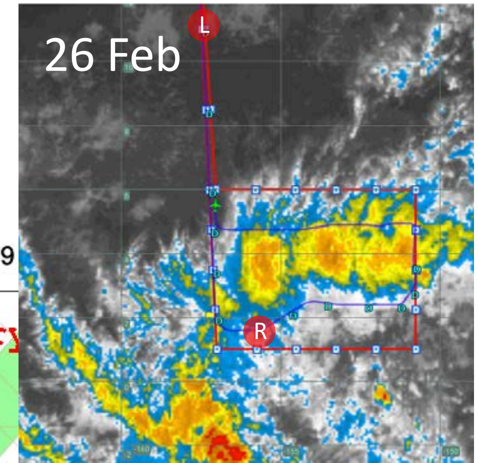
- G-IV performed "coordinated" missions with Global Hawk, C-130s, and Alpha Jet



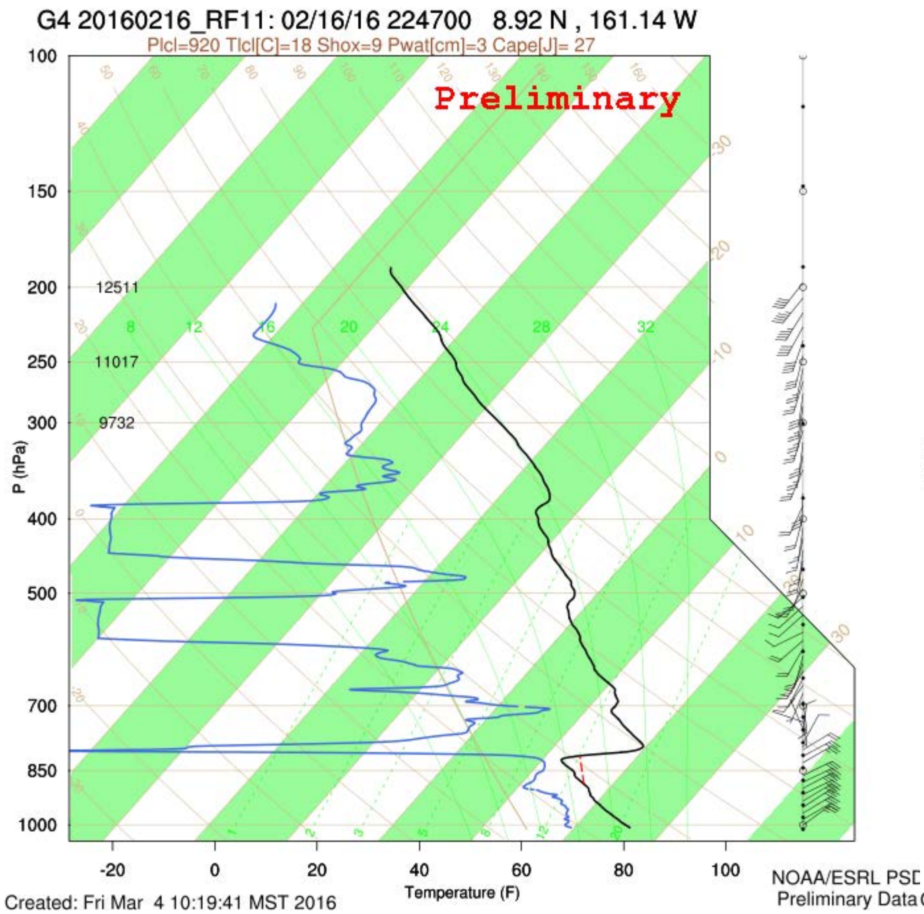
Convective Closure Module Soundings

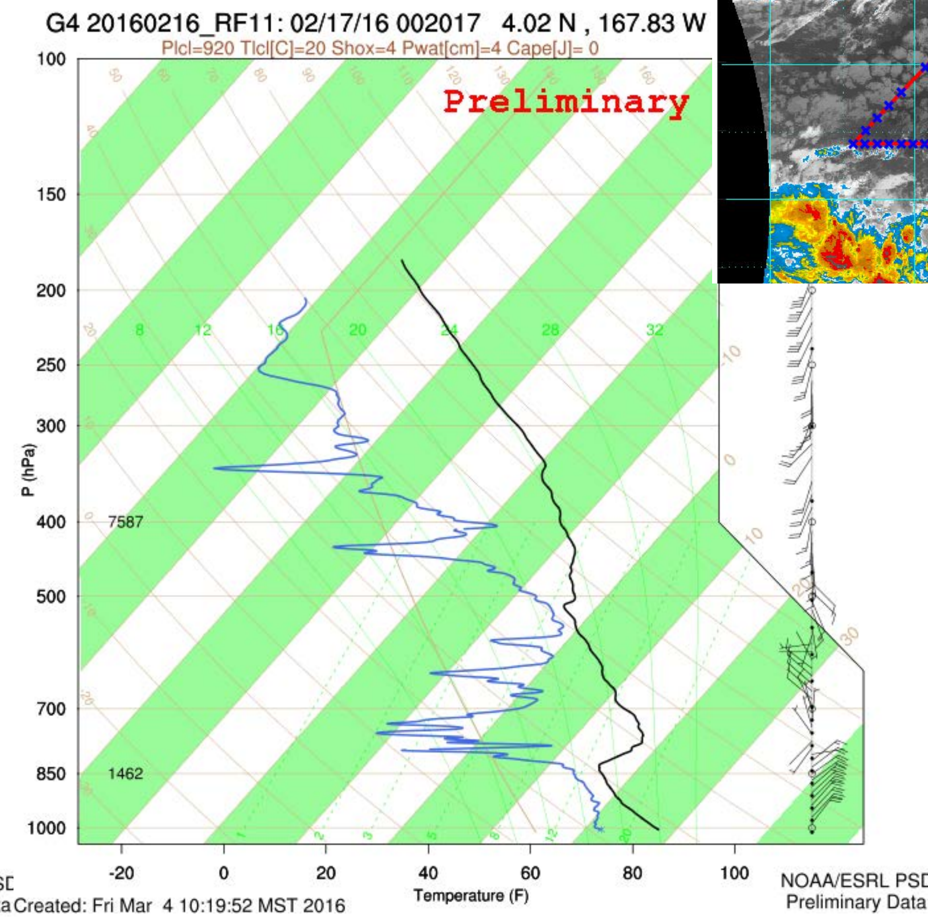


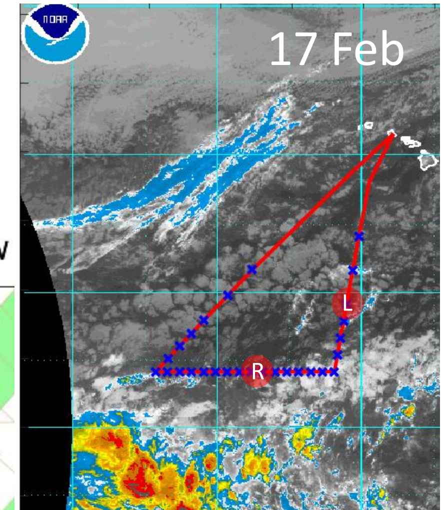




Convective Outflow Module Soundings

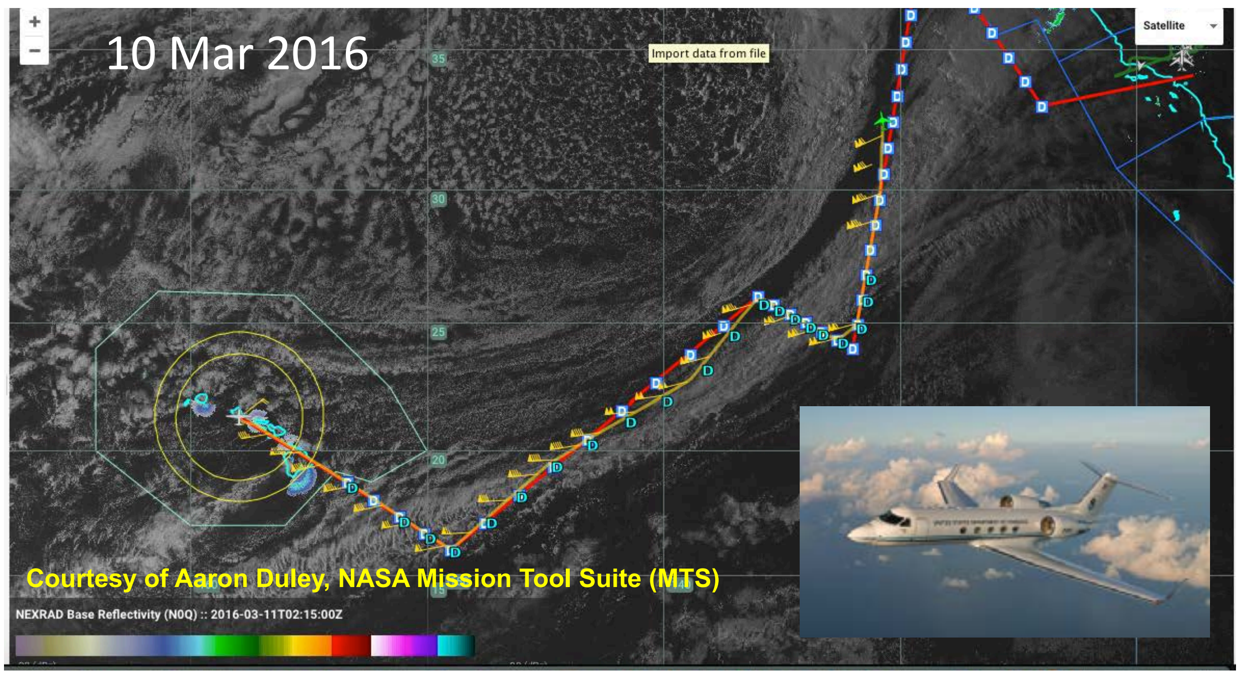


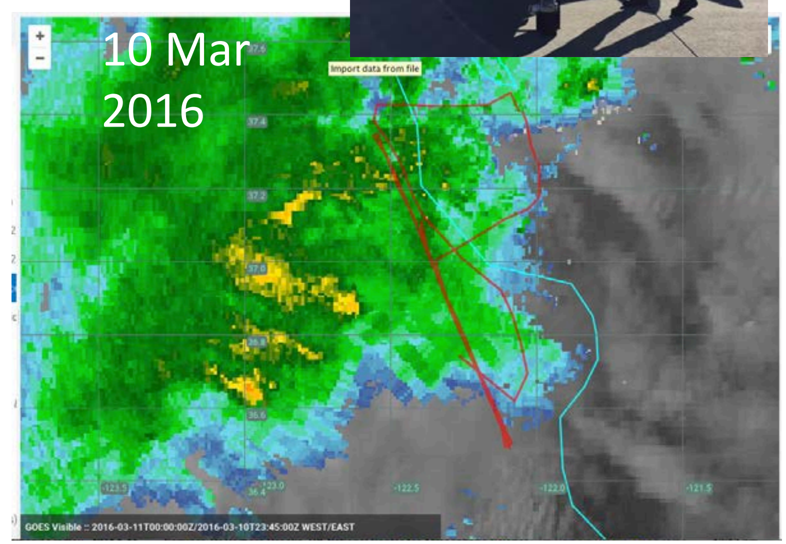




Tropical-Extratropical Linkages:
NOAA G-IV Coordinated Flight with Alpha Jet

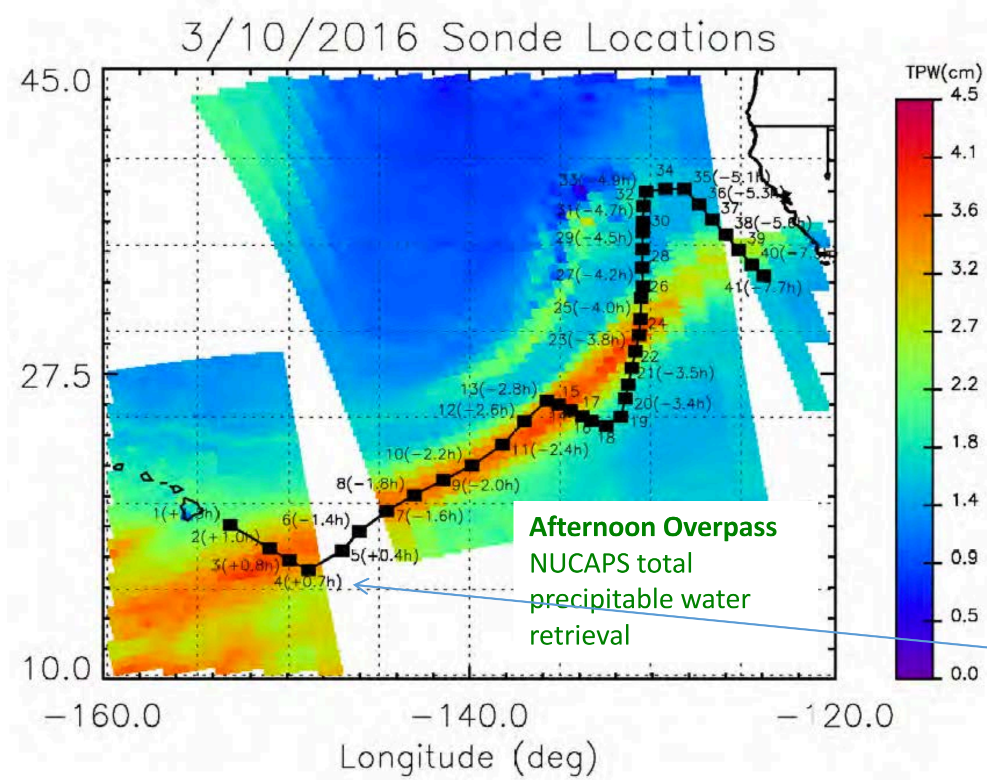
- G-IV flew multiple transects at 13 km altitude releasing dropsondes across a mature atmospheric river (AR) northeast of Hawaii making landfall along the northern CA coast
- Alpha Jet (based at NASA Ames in Bay Area) conducted a 1.5 hour stacked flight at low altitude in the warm sector of the AR immediately offshore





Dropsonde-Satellite-Model Comparisons

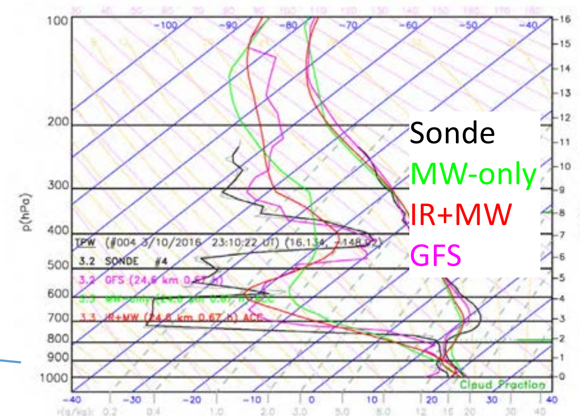
Morning and afternoon retrievals were performed from overpasses of Suomi-NPP based on microwave-only (ATMS) and combined infrared and microwave (CrIS+ATMS) sounding retrievals and compared with G-IV dropsondes and NCEP's Global Forecast System 3-9 hour forecasts



Colors: Total precipitable water from NOAA S-NPP satellite sounding algorithm (NUCAPS)

Boxes: Location of dropsondes from NOAA G-IV (time offset from overpass)

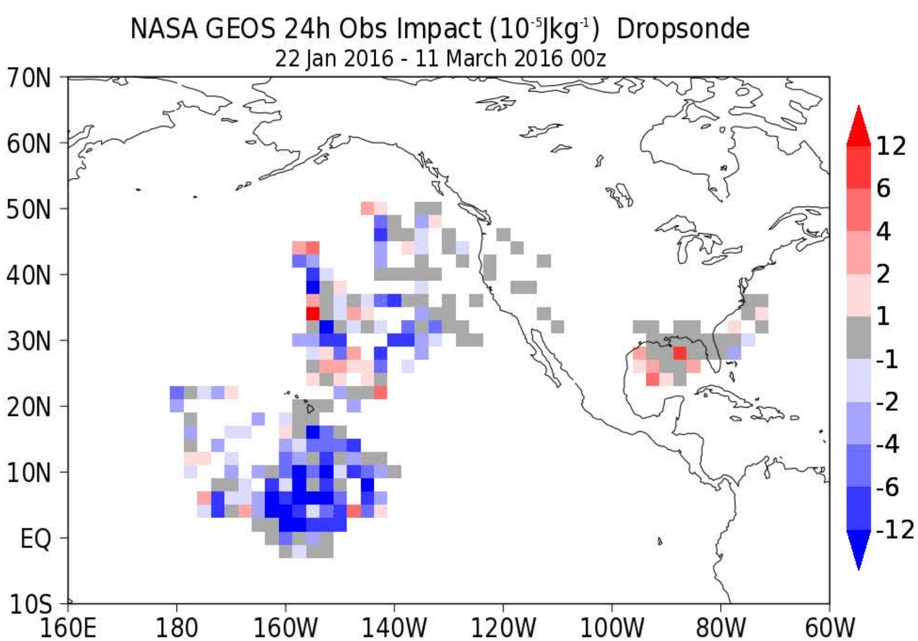
Dropsonde 4

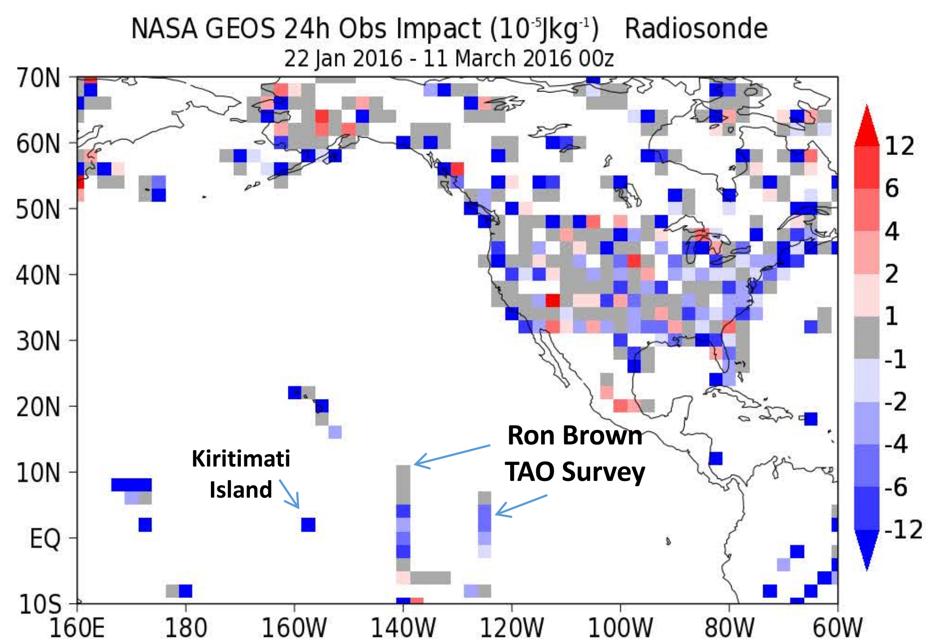


Courtesy of Antonia Gambacorta, Chris Barnet
Science and Technology Corporation (STC) and NESDIS

Preliminary Results – Forecast Improvement

- In NASA GEOS-5 model, G-IV dropsondes (left) and Kiritimati Island and Ron Brown radiosondes (right) reduce 24-hr forecast error as measured by global total moist energy
- Given all obs around the world, of those taken from 20°N to 20°S, ENRR dropsondes have the greatest contribution to reduction of error on a "per observation" basis





Courtesy of Ron Gelaro (NASA GMAO) and Gilbert Compo (NOAA ESRL PSD)

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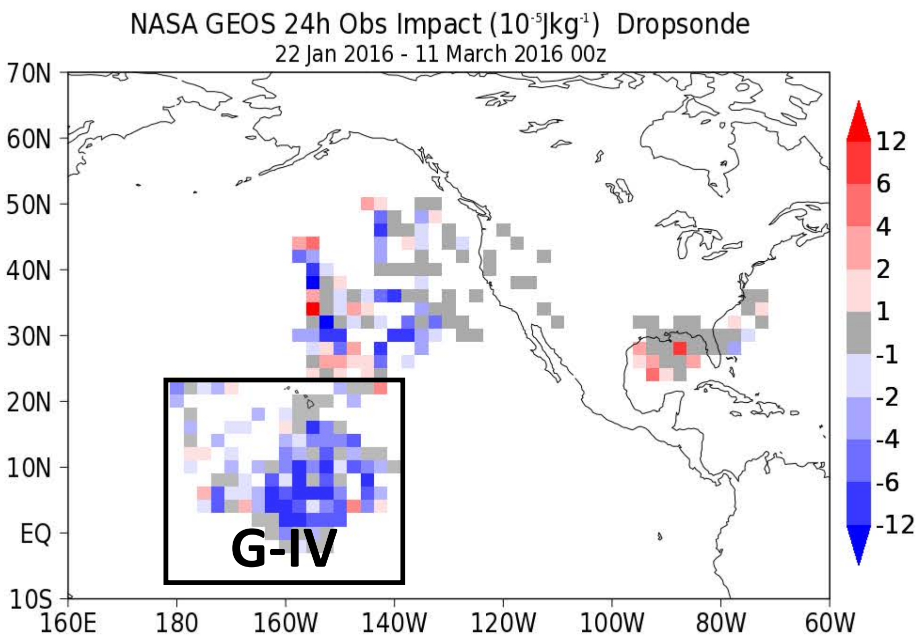

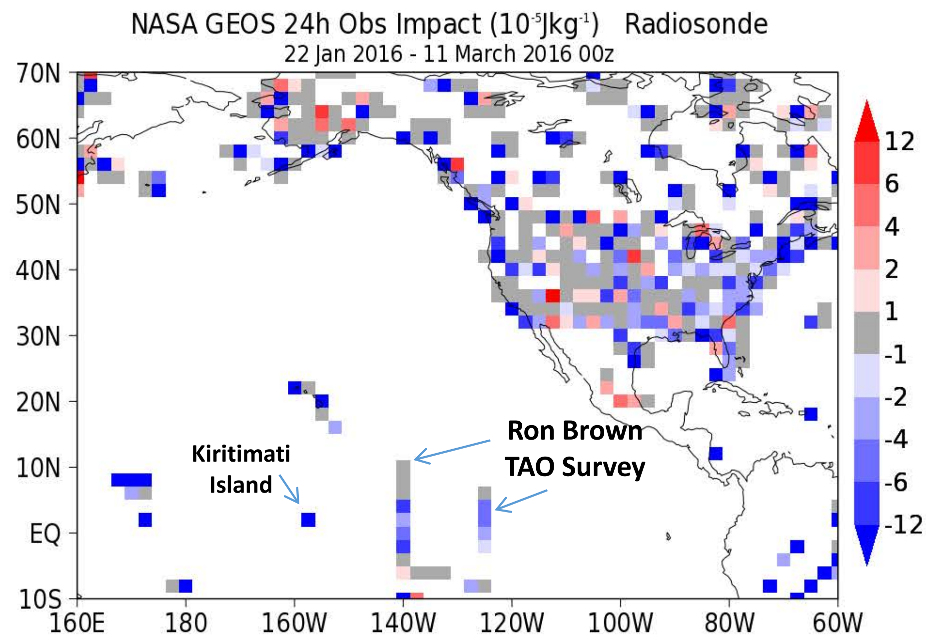

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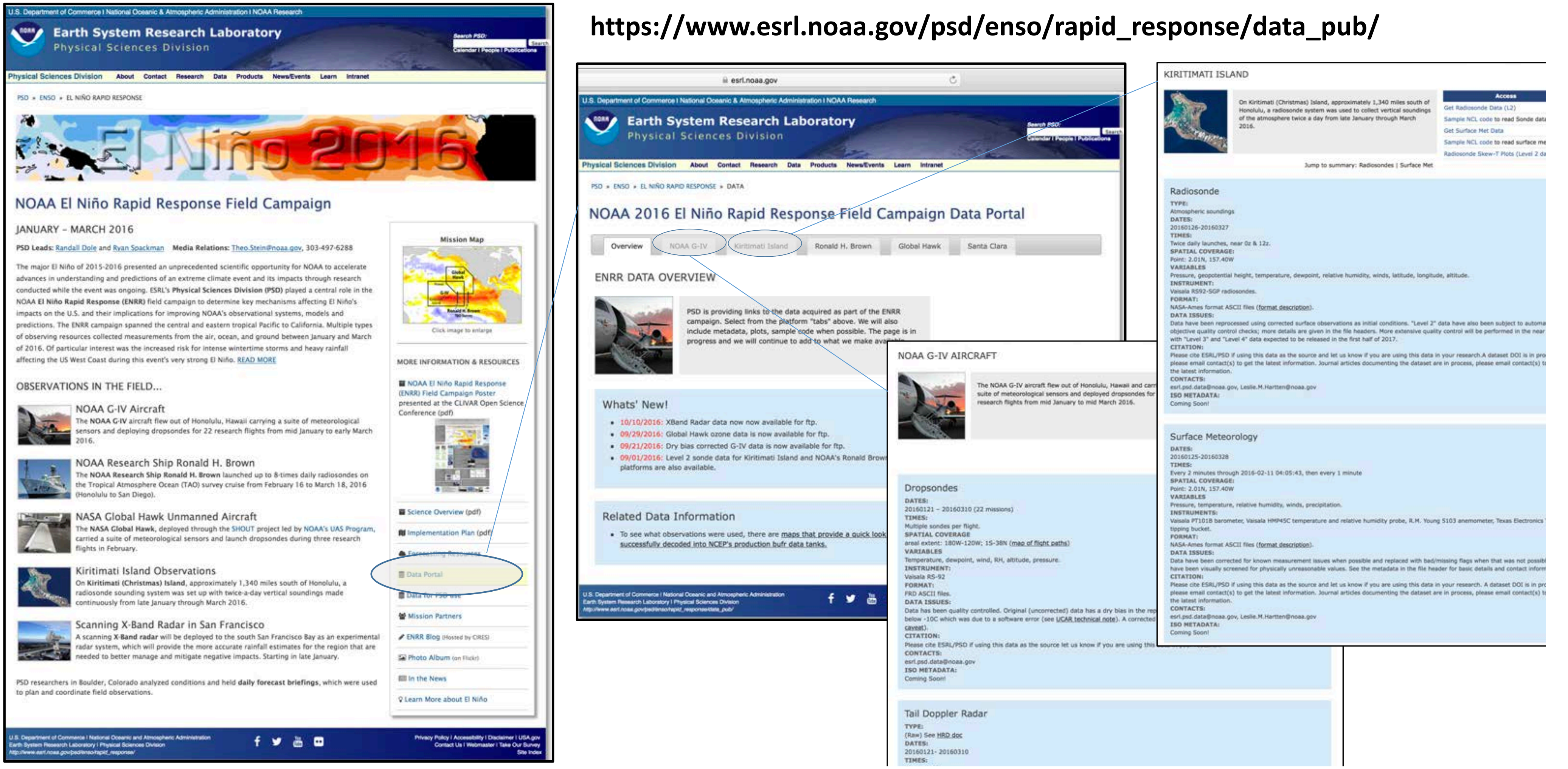
ENRR Data Portal

https://www.esrl.noaa.gov/psd/enso/rapid_response/data_pub/



Summary and Lessons Learned

- Despite programmatic challenges, NOAA demonstrated it is possible to *rapidly respond* to seasonal forecasts of a very strong El Niño
- ENRR was highly successful field campaign providing meteorological observations in the central tropical Pacific during the very strong El Niño
- ENRR provided an unprecedented dataset that will be examined for years to come
- Lesson Learned: Initiate partnerships with other agencies and academia/industry to leverage resources to better address system science before the rapid response
- Lesson Confirmed: Synchronize observing strategy with physical process understanding, satellite validation, and model development that informs the next generation global prediction systems

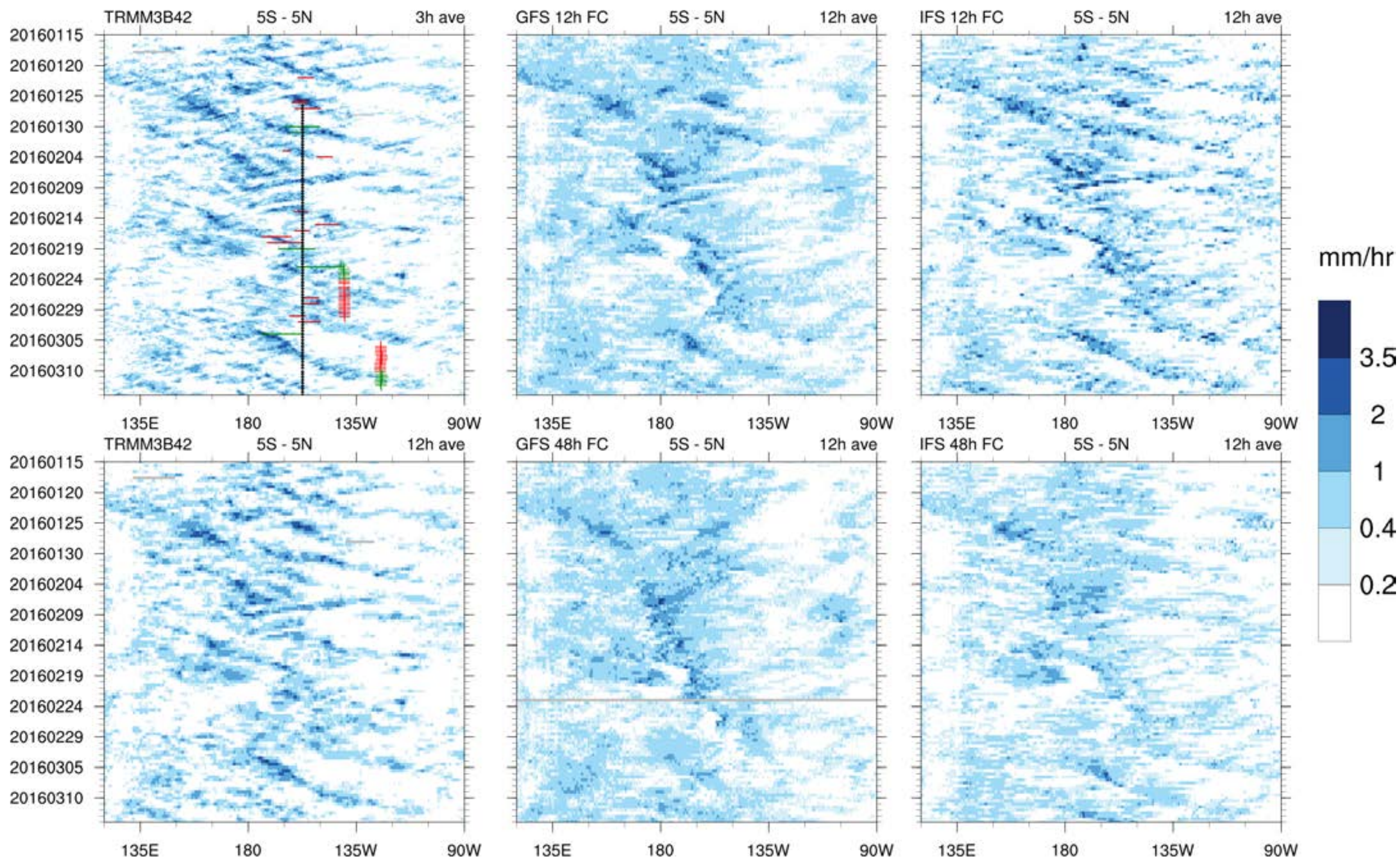
Next Steps and Future Directions

- **Model Improvements**: Examine the detailed physics associated with tropical convection and the linkages to jet processes in the extratropics and consider forecast model development approaches to implementing these schemes in process and operational global models
- **Forecast skill**: To what extent do thermodynamic and wind observations in data sparse regions reduce the error in 1 to 7-day forecasts? And how does this drive the observing strategy?
- **Integrated observing system development**: Use *in situ* measurements to refine satellite remote sensing algorithms to improve retrievals in data sparse regions
- **Outcomes from ENRR justify longer-term atmospheric and oceanic observations in data sparse tropical regions to examine air-sea interactions, large-scale convection and coupling to the midlatitude wave train for varying ENSO modes**

Supplementary Slides

Preliminary Results – Physical Process Understanding

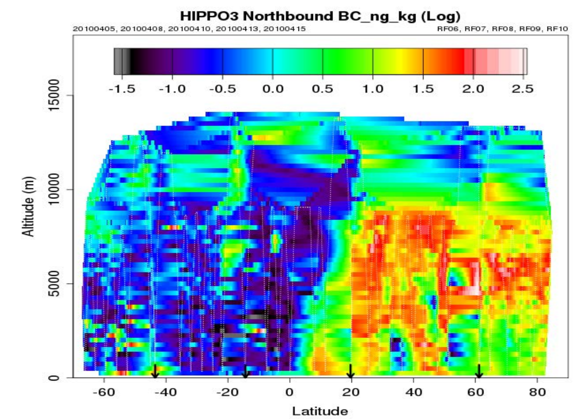
- Comparison of GPM data (left panels) with GFS and IFS model precipitation for 5°N to 5°S during ENRR period
- ENRR observations are overlaid on the Hovmöller in the upper left plot:
  - Kiritimati (black dots)
  - G-IV (long dashes)
  - Ron Brown (plus signs)
- IFS appears to better represent precipitation than GFS in tropics



Courtesy of Kiladis, Dias, Gehne (NOAA ESRL PSD)

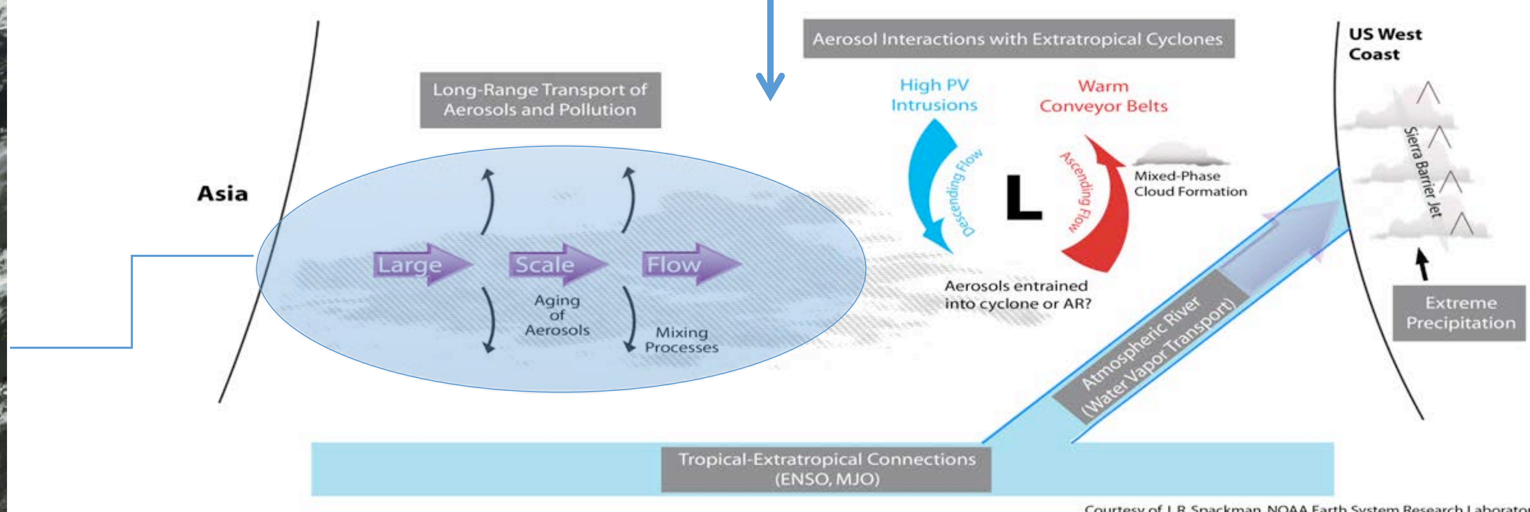
CalWater 2019 Opportunity

- DOE G-1 payload includes extensive suite of aerosols and cloud microphysics
- NOAA G-IV can provide key met observations (dropsondes, tail Doppler radar) to support aerosol/cloud evolution studies



Midlatitudes are extremely polluted downstream of East Asia in springtime

CalWater 2 Conceptual Framework



CalWater 2015 Campaign Management

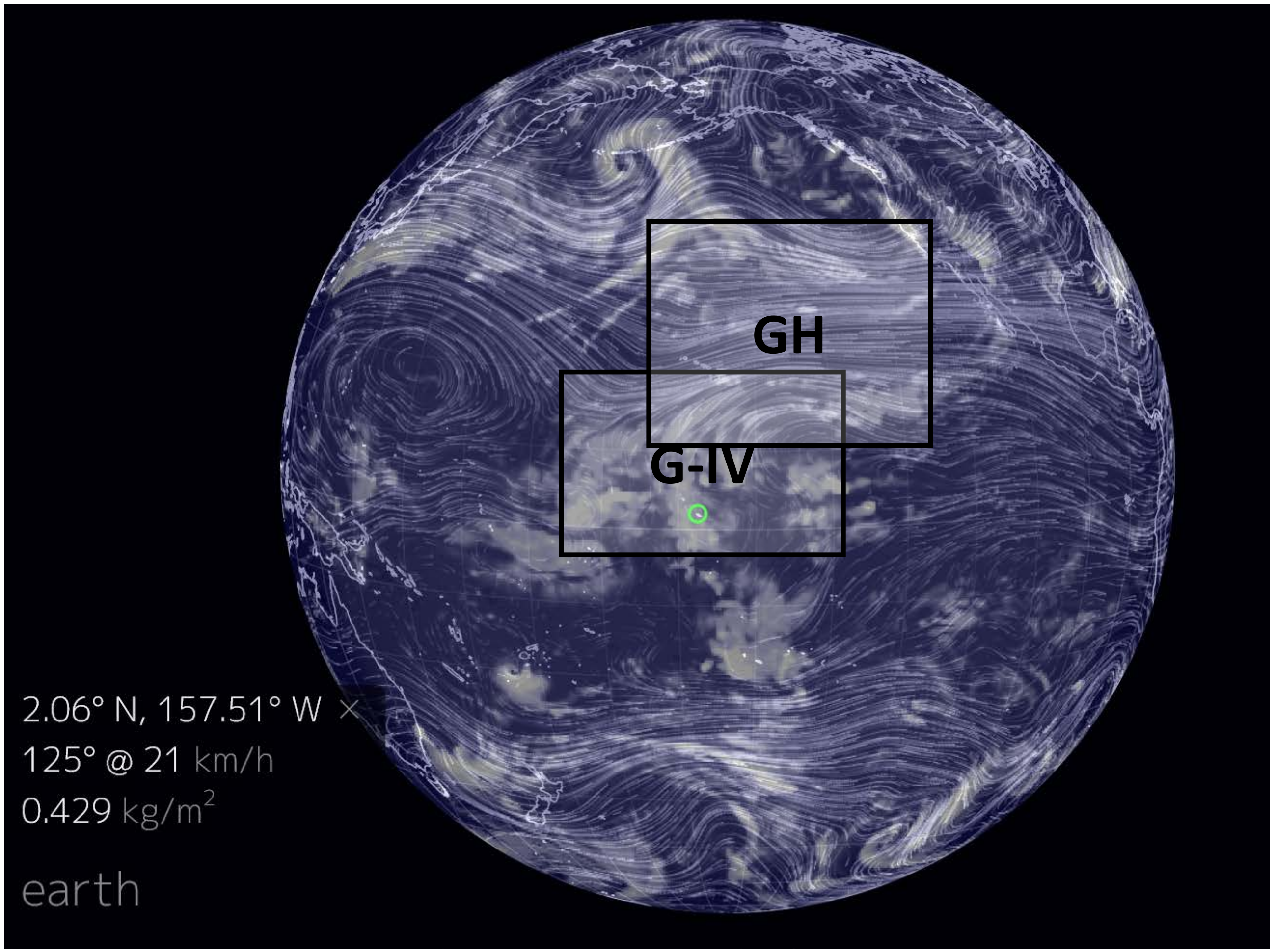
Mission Scientists
Marty Ralph – Kim Prather – Ruby Leung – Allen White

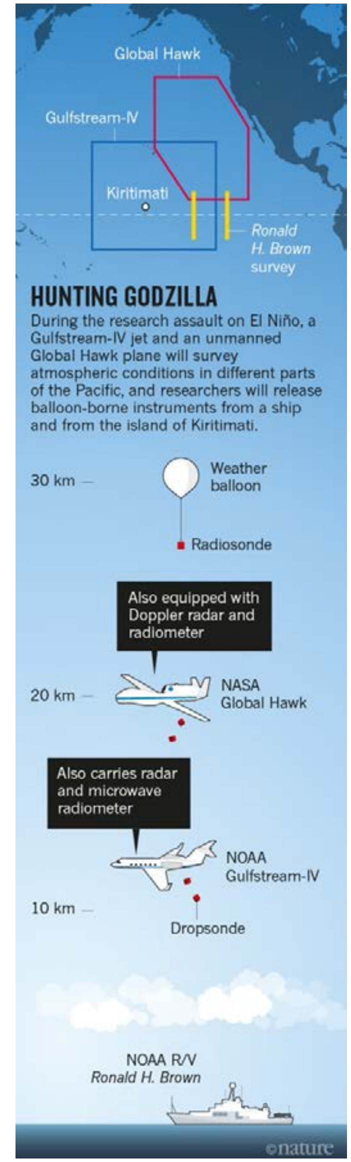
NOAA Ron Brown	**DOE G-I**	**NOAA P-3**	**NOAA G-IV**	**NASA ER-2**	**Bodega Bay**	**NOAA HMT**
Chris Fairall	Ruby Leung	Ryan Spackman	Janet Intrieri	Dave Diner	Kim Prather	Allen White

Working Group Planning Leads:
Flight Operations Science – Ryan Spackman
Forecasting – Jason Cordeira
Modeling and Analysis – Andrew Martin
Data Management – John Helly

Facilities Leads:
NOAA Ronald H. Brown – Adrienne Hopper
DOE AMF2 – Mike Ritsche and Amon Haruta
NOAA P-3 and G-IV – Paul Flaherty and Jack Parrish
DOE G-1 – Beat Schmidt and Mike Hubbell
NASA ER-2 – Brian Hobbs

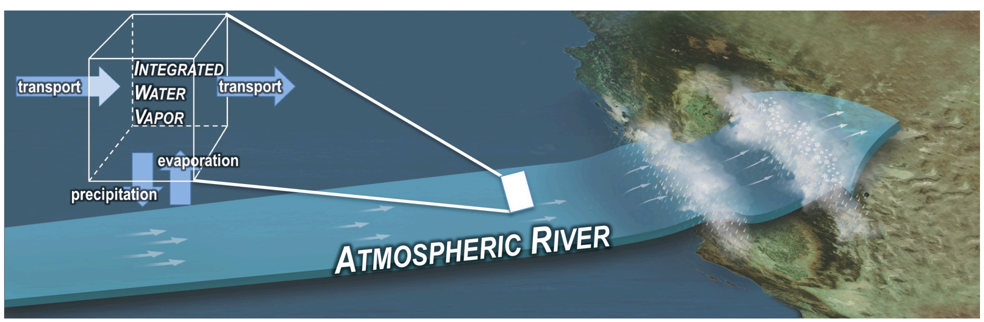
ENRR Implementation Strategy

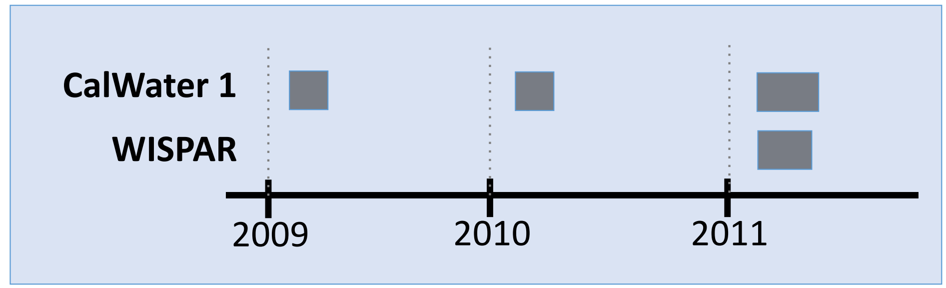


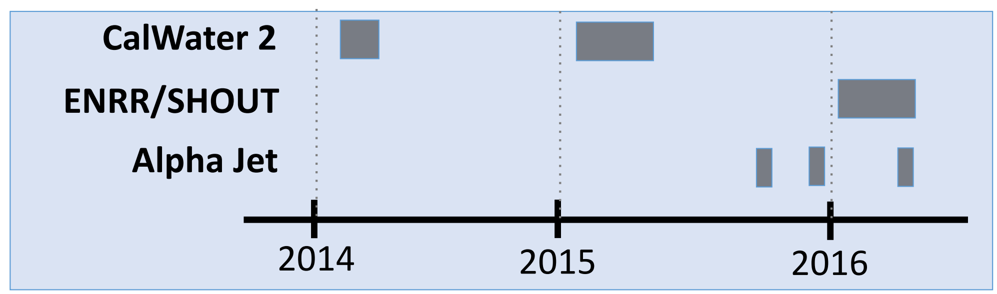


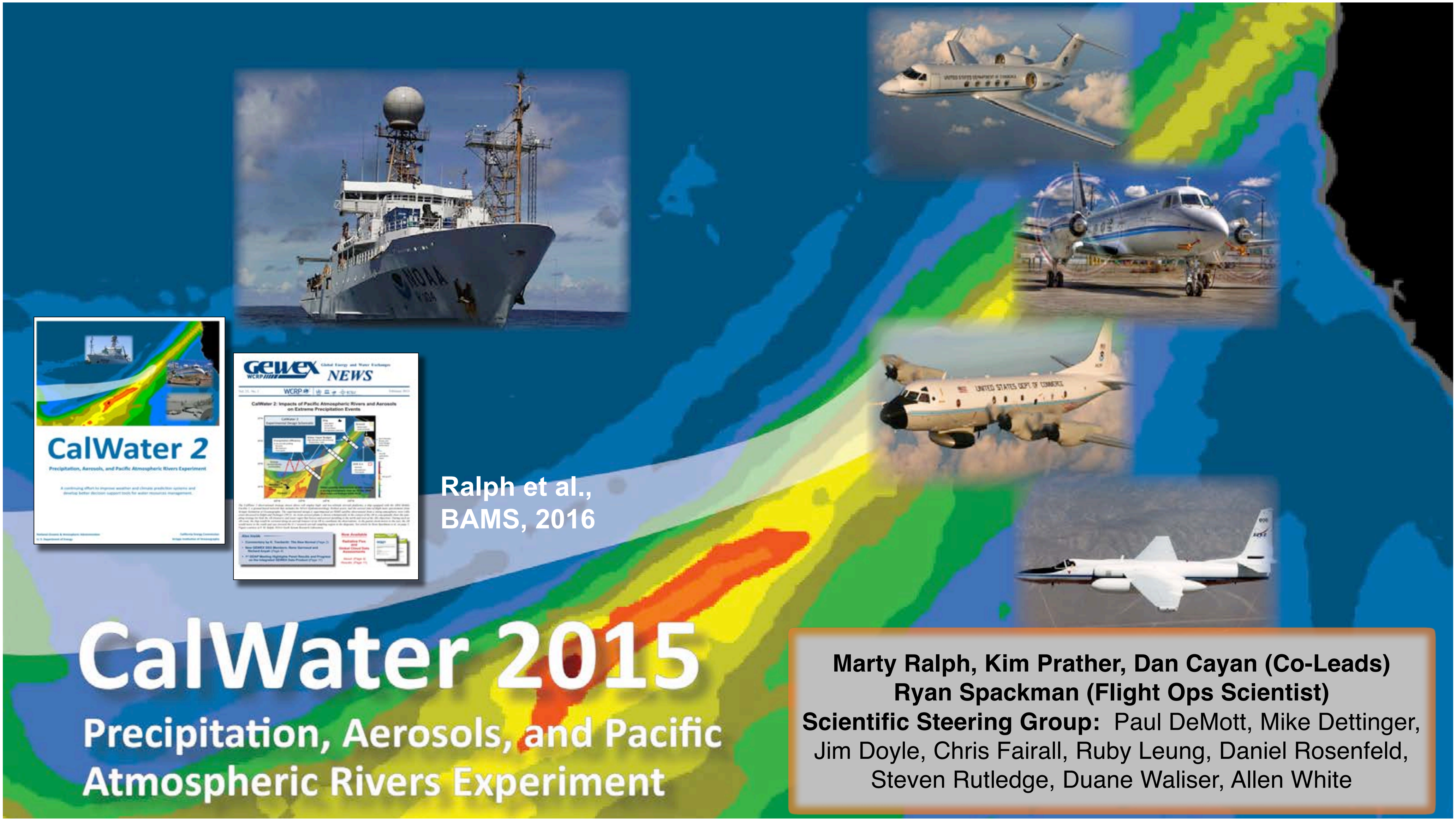
Recent Major Process Study Field Campaigns

- CalWater 1 studies in 2009-11 included cloud and aerosol payload on DOE G-1 to study AR landfall processes
- WISPAR: Winter Storms and Pacific Atmospheric Rivers with the NASA Global Hawk
- CalWater 2014 with NOAA G-IV meteorology payload
- CalWater 2015 with NOAA G-IV, P-3, DOE G-!, NASA ER-2, NOAA Ron Brown, Bodega Bay studied ARs
- ENRR/SHOUT: NOAA El Niño Rapid Response Field Campaign with the NOAA G-IV, NASA GH, USAF C-130s, and NOAA Ron Brown examined tropical-extratropical linkages during the strong 2016 El Niño
- Alpha Jet flights target landfalling AR processes





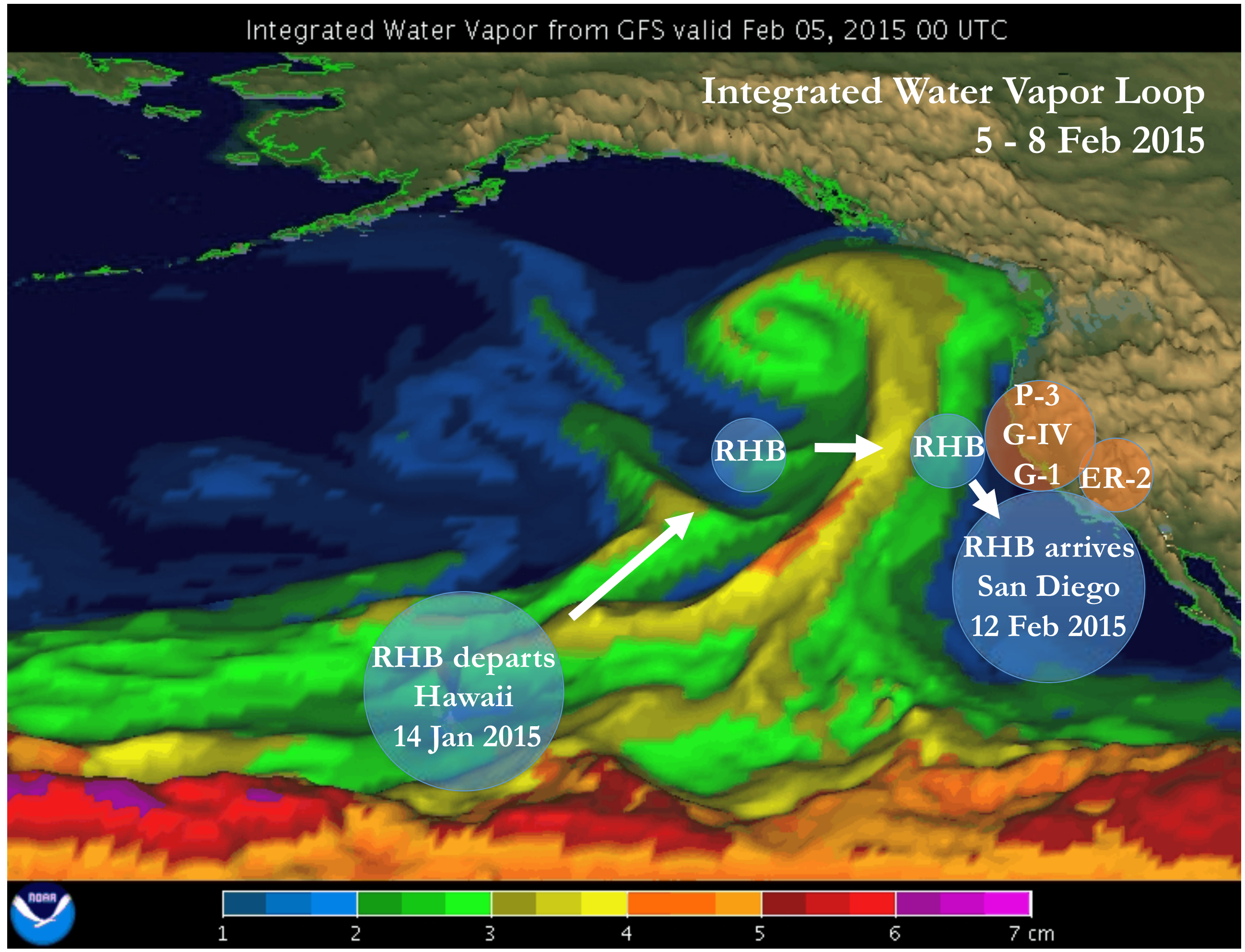



CalWater 2
GEWEX NEWS
Ralph et al.,
BAMS, 2016
CalWater 2015
Precipitation, Aerosols, and Pacific
Atmospheric Rivers Experiment
Marty Ralph, Kim Prather, Dan Cayan (Co-Leads)
Ryan Spackman (Flight Ops Scientist)
Scientific Steering Group: Paul DeMott, Mike Dettinger,
Jim Doyle, Chris Fairall, Ruby Leung, Daniel Rosenfeld,
Steven Rutledge, Duane Waliser, Allen White

CalWater 2015 Implementation

Intensive observations for 2 months in Jan-Feb 2015 with unprecedented interrogation of atmospheric rivers and related water vapor transport phenomena:

- 57 research flights
- 29 day research cruise
- 33 atmospheric river transects
- 444 dropsondes from P-3 and G-IV
- 300+ ship-based radiosonde launches
- Daily ship-based ozonesonde launches
- Coordination with NOAA HMT network and NSF-funded aerosol supersite observations

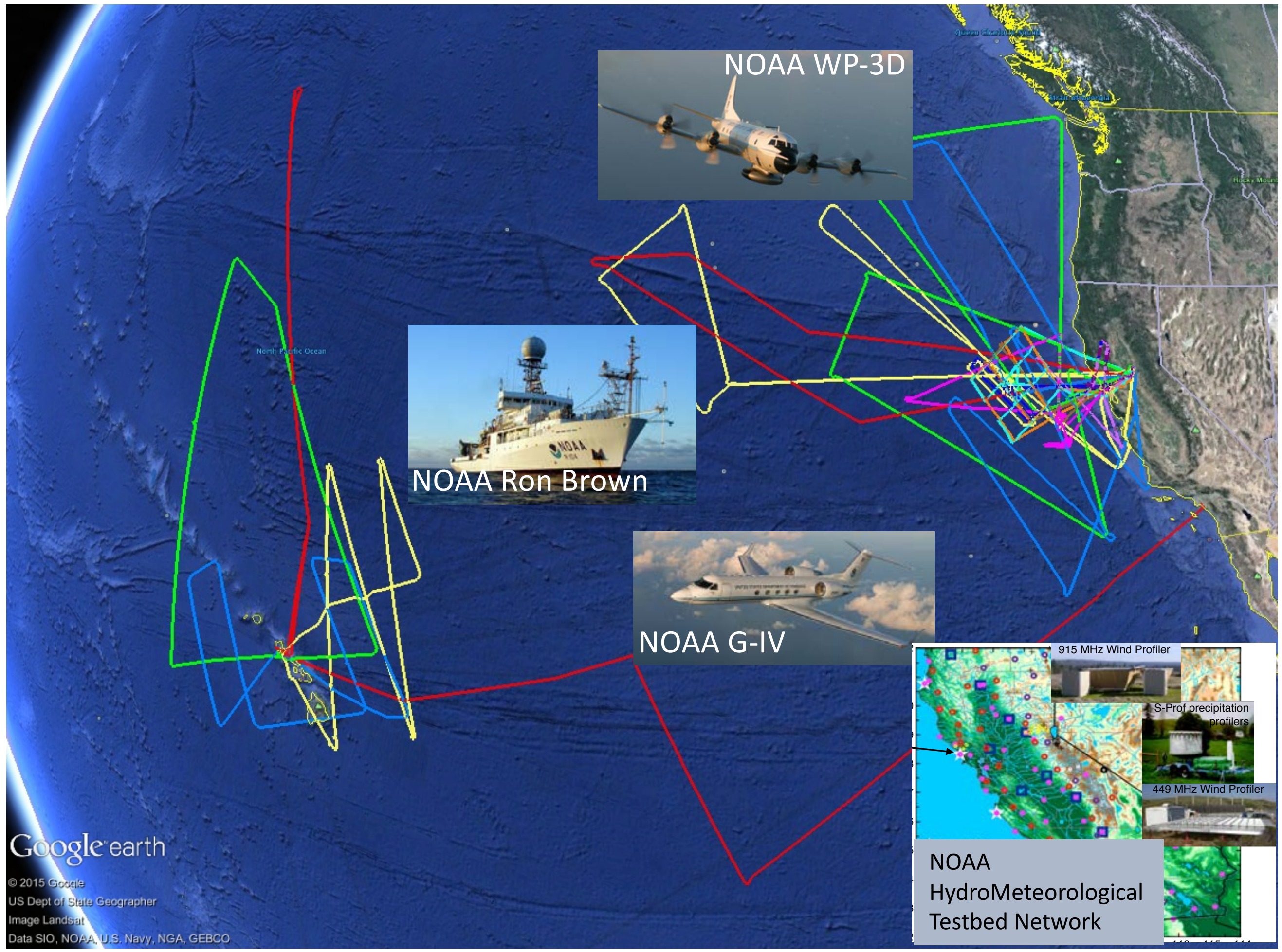


CalWater Website: www.esrl.noaa.gov/psd/calwater

Emerging CalWater 2015 Science Results

Several process studies are emerging from the intensive observations to address the CalWater 2015 science goals:

- Water vapor budget of ARs
- Air-sea flux interactions in ARs
- Aerosol-cloud interactions including role of direct and indirect aerosol impacts on precipitation
- Orographic control of precipitation and microphysical and barrier jet processes
- Tropical-extratropical connections
- Data denial/model integration studies with dropsonde observations



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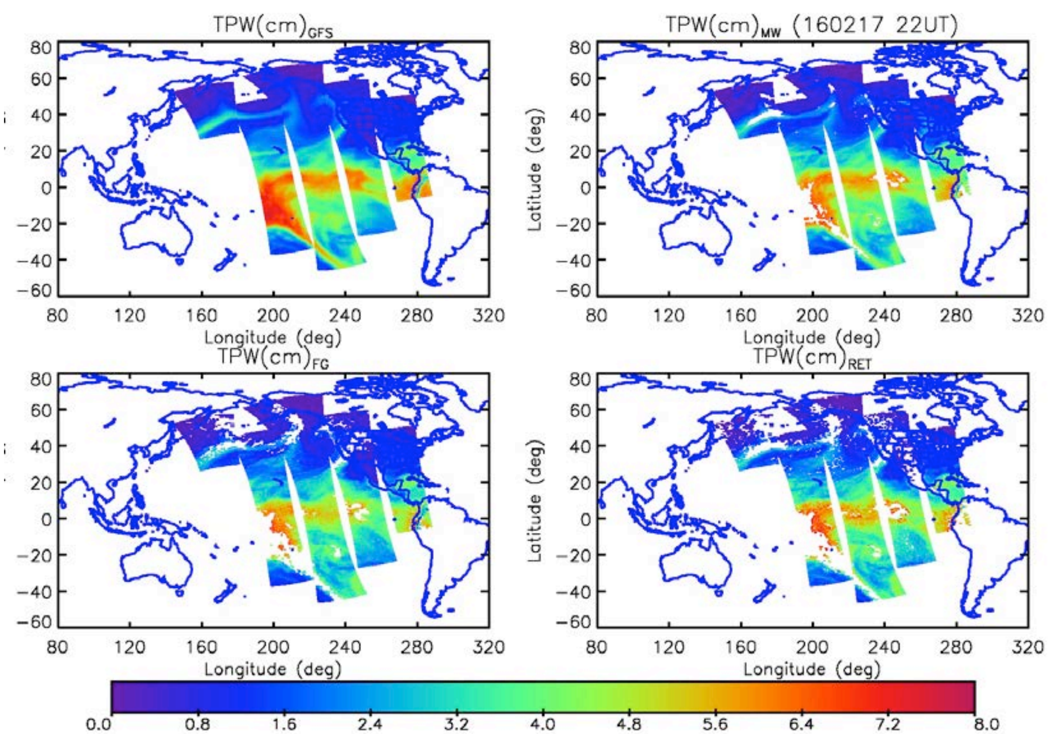
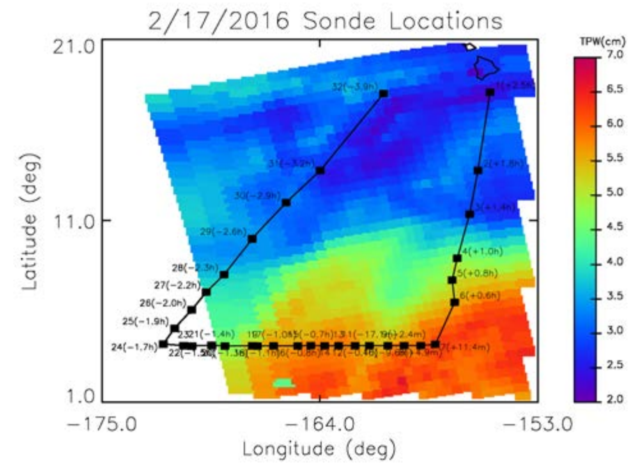
Using the NOAA Unique CrIS ATMS Processing System (NUCAPS) to assess hyper-spectral sounding capability during AR events: a test case from February 17, 2016



A snapshot of the full region

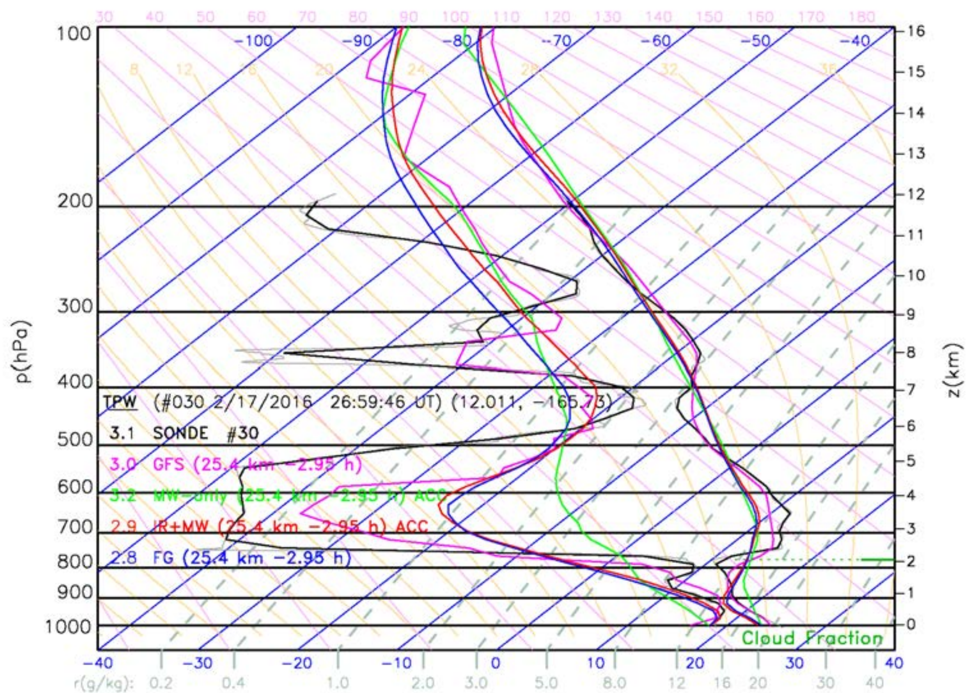


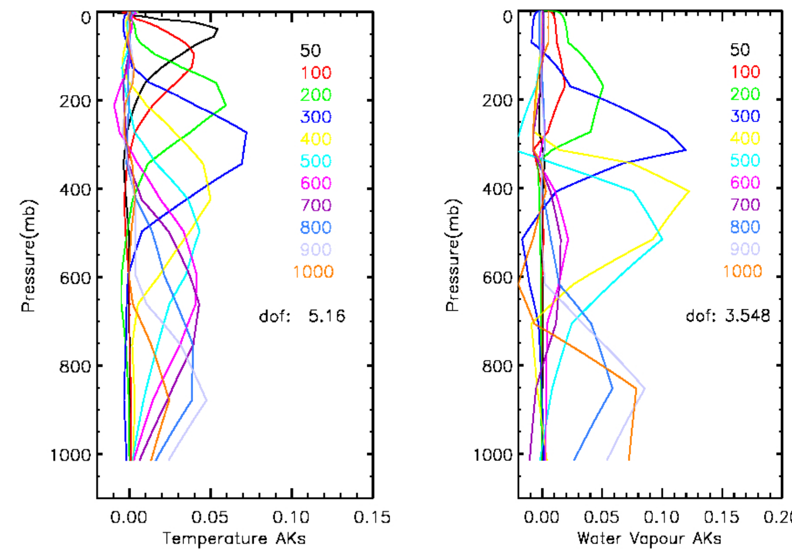
A close up figure over the flight path

➢Satellite data can provide near real time (~0.5 hour), 3D context to a high impact weather event

Courtesy of Antonia Gambacorta, Chris Barnet
Science and Technology Corporation (STC) and NESDIS

February 17, 2016:
a detailed comparison using dropsonde no. 30





➤Averaging Kernels provide insights on NUCAPS effective vertical resolution (broadness of the peaks) and information content (magnitude of the peaks)

➤ We are building a diagnostic capability to assess NUCAPS performance under high impact weather events. This will serve to make improvements on the algorithm and ultimately enable a more intelligent use of NUCAPS products.

Courtesy of Antonia Gambacorta, Chris Barnet
Science and Technology Corporation (STC) and NESDIS